RETRANSLOCATION OF TAGGED CARBON IN *AMBROSIA DUMOSA*

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ABSTRACT.— *Ambrosia dumosa* (A. Gray) Payne cuttings grown in solution culture were exposed to $^{14}CO_2$ to measure the distribution of labeled photosynthate among leaves, stems, and roots after 4, 24, and 48 h. For all sampling periods, the highest levels of ^{14}C were found in leaves and the lowest in roots; however, considerable ^{14}C had moved to roots in 48 h. In a 12-week study of *A. dumosa* in solution culture, plants increased in size more than 17 times and flowered and produced seeds. The plants had received $^{14}CO_2$ in photosynthesis at the start. The gradual loss of ^{14}C from the plants in the 12 weeks averaged 3.5 percent per week (coefficient of variation = 58 percent). This represents an average respiration rate of 0.21 mg C g dry weight^{-1} h^{-1}. This compares favorably with other means for determining respiration rate. The percentage of ^{14}C in the root portion of the plant varied little over 6 sampling periods, indicating that essentially none of the initially fixed ^{14}C left the roots during the 12 weeks of test. The ^{14}C entering fruits and seeds came from leaves only. The biomass of fruit parts resulted more from new photosynthate than from retranslocation from leaves. In a study in which *A. dumosa* plants were defoliated, little ^{14}C moved from roots to new shoot growth.

The United States International Biological Program Desert Biome has concentrated considerable research effort in studies of the carbon cycle. Certain questions could not be answered easily by conventional procedures, but tagging of plants with ^{14}C in photosynthesis was one means of obtaining answers for some questions (Wallace et al. 1979, Vollmer et al. 1975, 1976). Among the questions of concern were the following: Does carbon move from leaves to roots continuously, or as a pulse from that which has been newly fixed? Does carbon in roots contribute to new shoot growth? Does carbon in leaves or stems and/or roots contribute to fruit growth? What is the rate of carbon loss due to respiration? These questions could be approached with the ^{14}C technique under controlled conditions.

MATERIALS AND METHODS

Ambrosia dumosa (A. Gray) Payne cuttings were grown for 30 days in solution culture in a glasshouse, at which time the shoots were about 15 cm tall. The shoots were then exposed to $^{14}CO_2$ (about 5 uCi/plant) in plastic bags for 2 h. Two plants each were separated into leaves, stems, and roots after 4, 24, and 48 h. The methods generally were like those previously used (Bamberg et al. 1975).

Two-month-old *A. dumosa* cuttings growing in 3700 ml nutrient solutions in a glasshouse were exposed to $^{14}CO_2$ by the general procedures described above. Three plants were separated into plant parts for ^{14}C determination after 24 h, 1 week, 2 weeks, 4 weeks, 8 weeks, and 12 weeks to determine changes in distribution with time.

To ascertain movement of previously fixed ^{14}C from crown and root materials to shoots, an experiment was conducted in which four *A. dumosa* plants, each growing in 1600 g soil, were exposed to $^{14}CO_2$ as above. Leaves of the plants were sampled at 2 h and 24 h. After 48 h the shoots of the plants were cut off. The shoots were allowed to regrow and at 78 days the plants were removed from the soil and separated into parts, including fine roots separated by salt-flotation with $MgSO_4$. All plant parts were counted for ^{14}C by Q-gas counting.

RESULTS AND DISCUSSION

Table 1 shows the distribution of ^{14}C in leaves, stems, and roots of *A. dumosa* plants at 4, 24, and 48 h after labeling. Most of the

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label was confined to the leaves and stems, with only 4.7–7.4 percent going to the roots, even though they comprised 15–19 percent of the biomass. Changes with time in the percentage of ^{14}C in the different plant parts were not readily apparent, although the proportion of root ^{14}C might have increased slightly. As the experiment progressed, the amount of ^{14}C per unit weight decreased due to both dilution by new growth and respiratory loss. Roots maintained a relatively constant ^{14}C:weight ratio, but that of leaves and stems dropped sharply. This seems to indicate that most of the gains and losses of carbon during this 48-hour period occurred in the latter two structures or that dilution was involved.

Redistribution or reallocation of carbon in *A. dumosa* was studied over a 12-week period in a solution culture experiment (Table 2). Changes were followed over six different sampling times. The plants flowered and fruited during the test, which permitted a measure of mobility of the carbon from the initially fixed ^{14}C. Three plants were harvested at each time period for the measurement.

The plants increased in size over 17 times during the course of the 12-week experiment. The respiratory loss of the ^{14}C was relatively small. The estimates were about 9 percent at one week, 4 percent for 2 weeks, 14 percent for 4 weeks, 33 percent for 8 weeks, and 22 percent for 12 weeks. The irregularity of the values indicate variability. A normalized value for all five values results in 3.5 percent loss per week as an average. The standard deviation for the 3.5 percent value is 2.07 percent, with a coefficient of variation of 58 percent.

If this value (3.5 percent per week) represents a respiration rate, it would be 2.1×10^{-4} mg C mg dry weight$^{-1}h^{-1}$ or 0.21 mg C g dry weight$^{-1}h^{-1}$ at any point in the history of these plants. This compares fairly well for actual respiration measurements. It represents the respiration rate for the active growing stages and not for dormancy for this species (Vollmer et al. 1976).

The percentage of ^{14}C in the root portion

TABLE 1. Distribution of ^{14}C in *Ambrosia dumosa* grown in solution culture after tagging with $^{14}CO_2$ in photosynthesis.

Hours after labeling	Leaf	Stem	Root	Whole plant
		Dry weight, mg		
4	642	409	252	1303
24	1025	429	254	1708
48	1215	616	376	2207
		Percent plant parts by weight		
4	49.3	31.4	19.3	100
24	60.0	25.1	14.9	100
48	55.1	27.9	17.0	100
		cpm/plant part (× 1000)		
4	424	159	25.2	608
24	437	145	35.3	617
48	366	147	51.0	554
		Percent of ^{14}C in plant parts		
4	69.7	26.2	4.1	100
24	70.8	23.5	5.7	100
48	66.1	26.5	7.4	100
		cpm/g (× 1000)		
4	660	389	100	467
24	427	339	139	362
48	301	240	109	251

of the plants varied little for the six sampling periods, even when seeds were produced. It was about the same at 24 h (5.1 percent) as at 12 weeks (5.8 percent). We may conclude, therefore, that the ^{14}C moved to roots only on the day of fixation. None left the roots thereafter during the 12 weeks of test. More dry matter than ^{14}C was moved to the fruiting parts and seeds, implying that most of the photosynthate used for fruiting was new. The ^{14}C that was translocated to seeds seemed to come from leaves only.

Redistribution of carbon in *A. dumosa* was further studied with plants grown in soil. Four plants exposed to $^{14}CO_2$ were defoliated after 2 days, and a portion of the stem was also removed. Any ^{14}C thereafter found in leaves and new stems had to be translocated from old parts. After 78 days following defoliation 8 percent of the ^{14}C was in the leaves, and 0.5 percent was in new stems with more than 57 percent in roots (Table 3). This indicates as in the other tests that ^{14}C is not readily moved from roots after initial fixation. The small amount of ^{14}C that did move to the leaves probably was mobilized when the leaves were initiated. At 78 days, 24 percent of the plant biomass was leaves with 8 percent of the ^{14}C. Thirty percent of the plant biomass was roots with 57.5 percent of the ^{14}C.

TABLE 2. Dry weight and distribution of dry weight and ^{14}C in plant parts at different times following exposure of *Ambrosia dumosa* to $^{14}CO_2$.

Plant part	2 h	1 week	2 weeks	4 weeks	8 weeks	12 weeks
			Dry weight, mg/plant			
Leaf	992	1,191	3,350	3,520	7,655	18,361
Stem	700	1,454	1,758	3,226	6,752	10,150
Transition	58	94	133	212	224	1,078
Root	190	397	576	890	2,304	2,555
Seed	—	—	—	2,023	2,673	1,816
Total	1,940	3,856	5,817	9,871	19,608	33,960
			cpm/g			
Leaf	553,267	274,933	163,347	109,760	41,950	18,990
Stem	338,980	124,540	109,673	61,447	20,240	17,910
Transition	72,695	62,120	91,013	34,860	26,020	16,780
Root	222,033	112,987	78,693	54,513	17,630	14,830
Seed	—	—	—	38,920	18,910	36,360
			cpm/plant			
Leaf	548,841	525,395	547,212	386,355	321,127	348,675
Stem	237,286	181,081	192,806	198,228	136,660	181,787
Transition	4,216	5,839	12,105	7,390	5,828	18,089
Root	42,186	44,856	45,327	48,516	40,620	37,891
Seed	—	—	—	78,735	50,546	66,030
			Dry weight/total plant weight (percent)			
Leaf	51.1	49.6	57.6	35.7	39.0	54.0
Stem	36.1	37.7	30.2	32.7	34.5	29.9
Root	9.8	10.3	9.9	9.0	11.8	7.5
Transition	3.0	2.4	2.3	2.1	1.1	3.2
Seed	0.0	0.0	0.0	20.5	13.6	5.4
Total	100.0	100.0	100.0	100.0	100.0	100.0
			cpm/plant (percent)			
Leaf	65.9	69.4	68.6	53.7	57.9	53.4
Stem	28.5	23.9	24.2	27.6	24.6	27.9
Transition	0.5	0.8	1.5	1.0	1.1	2.8
Root	5.1	5.9	5.7	6.8	7.3	5.8
Seed	0.0	0.0	0.0	10.9	9.1	10.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 3. Distribution of ^{14}C in *A. dumosa* plants 78 days after exposure of the shoots to $^{14}CO_2$ and 76 days after removal of all the leaves and the stems from the plants.*

Plant part	Dry wt g/plant	cpm/g	cpm/ plant	Percent dist.	SD of percent dist.	CV of percent dist. percent.
Leaves	2.02	610	1232	8.0	2.50	31
New stems	0.53	135	72	0.5	0.07	13
Old stems	2.53	1520	3846	24.9	7.31	29
Crown	0.82	1725	1415	9.1	6.03	66
Big root	0.37	2580	955	6.2	3.18	51
Small root	0.33	3525	1163	7.5	1.47	20
Fine root	1.82	3730	6789	43.8	11.78	27
Totals or means	8.42	1838	15472	100.0	—	—

*Leaf concentration of ^{14}C at 2, 24, and 48 h from exposure to $^{14}CO_2$ were 82,135, 39,670, and 37,230 cpm/g dry weight, respectively.

Leaf concentrations of ^{14}C at 2 h, 24 h, and 48 h from exposure to $^{14}CO_2$ (82,135, 39,630, and 37,230 cpm/g) indicated that either there was considerable loss due to dark respiration in this C-3 plant or that this period was the time in which translocation to roots primarily occurred.

It can be argued that these experiments under partially controlled conditions may not represent field conditions adequately. In the companion study with *Larrea tridentata* (Sesse & Moc ex DC.) Cov. in the field (Wallace et al. 1980), ^{14}C persisted in plants, especially in the roots, for more than three years after time of fixation.

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LITERATURE CITED

BAMBERG, S. A., G. E. KLEINKOPF, A. WALLACE, AND A. VOLLMER. 1975. Comparative photosynthetic production of Mojave Desert shrubs. Ecology 56:732–736.

VOLLMER, A. T., S. A. BAMBERG, A. WALLACE, AND J. W. CHA. 1975. Plant productivity and nutrient interrelationships of perennials in the Mohave Desert. US/IBP Desert Biome Res. Memo 75-7. Utah State University, Logan, Utah.

VOLLMER, A. T., A. WALLACE, J. W. CHA, AND T. HARTSOCK. 1976. Plant productivity and nutrient interrelationships of perennials in the Mohave Desert. US/IBP Desert Biome Res. Memo. 76-6. Utah State University, Logan, Utah.

WALLACE, A., S. A. BAMBERG, AND J. W. CHA. 1977. Partitioning of photosynthetically fixed ^{14}C in perennial plants of the northern Mohave Desert. Pages 144–148 *in* IBP/Interbiome Symposium: the belowground ecosystem: a synthesis of plant-associated processes, Range Sci. Series No. 16, Colorado State University, Fort Collins, Colorado.

WALLACE, A., E. M. ROMNEY, AND J. W. CHA. 1980. Persistence of ^{14}C labeled carbon in *Larrea tridentata* up to 40 months after photosynthetic fixation in the northern Mojave Desert. Great Basin Nat. Mem. 4:170–174.